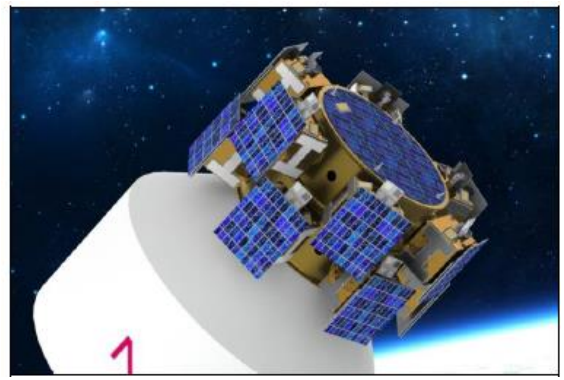
Optimized Orbit for Secondary Heliophysics Payloads: Propulsive ESPA



Dan Moses

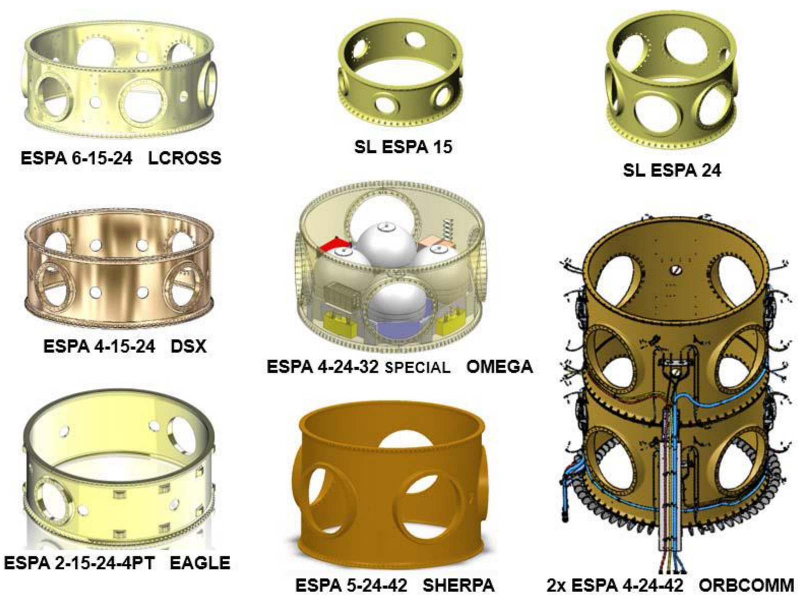
Heliophysics Subcommittee Meeting

1 March 2016

ESPA:

EELV (Evolved Expendable Launch Vehicle) Secondary Payload Adapter

Developed by AFRL & Moog CSA for DoD Space Test Program
Wide, successful usage (all EELV types) established a *de facto* secondary payload standard

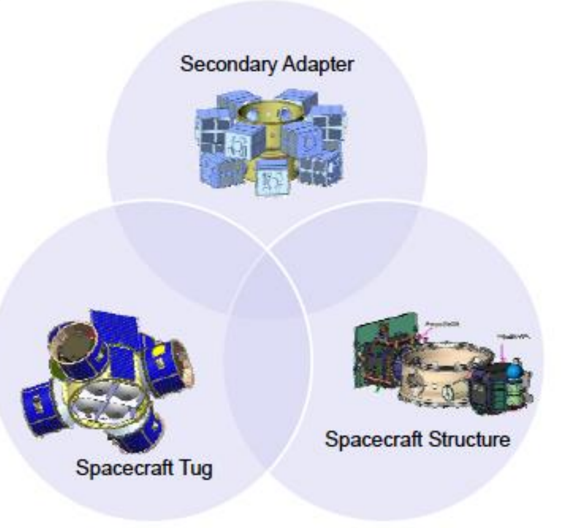


Example ESPA configurations commercially available from Moog CSA since 2010

- ESPA (2000)
  - Flown on all EELV (Atlas V, Delta IV & Falcon 9)
  - Defined ESPA-class small-sat
    - 180kg
    - 410liters volume (61cmx71cmx97cm)
    - CG offset 51cm from payload I/F
- ESPA Grande (2004)
  - 24-inch port size interface for 700-lb small sats
- Small Launch ESPA (2007) for 38.8-inch LV interface
  - Rings with smaller LV interfaces (31.5”& 36.9”)
  - Secondary interfaces up to 15 inches
- Large diameter rings (2009) for LV diameters to 120 inch
- EAGLE ESPA (2012) integral 4-point mount
- Reduced weight rings for mission-specific payloads
  - 2012 OMEGA mission for science constellation deployment

Add Propulsion to ESPA: Achieve optimized orbit(s) & more

- Passive secondary payloads limited in
  - Orbit available
  - Deployment sequence flexibility
  - Upper stage restart capability
- Solutions:
  - Propulsion on individual secondary payloads
    - Severe limits on total energy by primary payload risk tolerance result in very limited options – NOT GOOD
  - Propulsion on standardized secondary carrier (ESPA Ring)
    - Reduced interfaces and risks
    - Added benefits
      - Development of long-term host for secondary payloads
      - Spacecraft tug
- Successful example
  - LCROSS (Lunar Crater Observation and Sensing Satellite)
    - LCROSS successfully flew as a <u>secondary</u> mission with the Lunar Reconnaissance Orbiter(LRO) spacecraft (2009)
    - First ESPA Ring with on-board propulsion



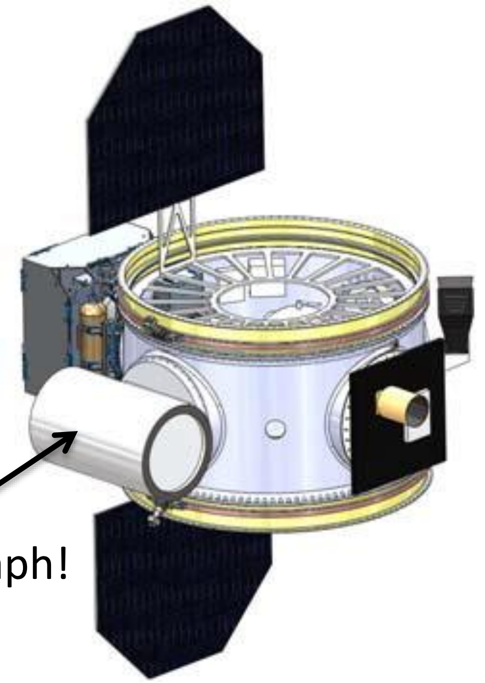
Overlapping Applications

LCROSS & Centaur Upper Stage

Example Mission: ELLIE[1]

GTO secondary payload launch to L1 Orbit

- Two missions proposed for this orbital maneuvering vehicle
  - DISCOVR follow on at L1
  - Solar sail tech. demo. - separates during L1 transfer
- Total payload mass 212.7kg,
  - 32.7kg for sun observing instruments
  - 180kg for technology demonstration payload
- 3 year operational design life at L1



Deployments & Maneuvers	OMV Delta-V	OMV Fuel Required	Duration after Launch
Perigee Burn 1	250 m/s	91.7 kg	Days 1-14
Perigee Burn 2	250 m/s	82.3 kg	
L1 Transfer Orbit Injection Maneuver	250 m/s	73.9 kg	
Trajectory Correction	10 m/s	2.8 kg	
L1 Halo Orbit Insertion	50 m/s	13.8 kg	3 months
Stationkeeping (15 m/s per year)	75 m/s	20.1 kg	5 years
TOTAL	885 m/s	284.6 kg	

CONOPS

- Secondary launch into GTO below a commercial GEO spacecraft
- Three large burns raise the orbit and send ELLIE into the L1 transfer orbit.
- The technology demonstration payload deployed
- Halo orbit insertion ≈3 months later.

[1] "Rideshare and the OMV: the Key to Low-cost Lagrange-point missions" by Pearson, Stender, Loghry, Maly et al. Paper SSC15-II-5 presented at the August 2015 Small Satellite Conference in Logan, Utah.

ESPA Ring Missions with Propulsion

- LCROSS 2009 by Northrop Grumman for NASA Ames
  - “Shepherding satellite” and lunar impactor
- AFRL small business programs (SBIR) 2007-2010
  - Millennium Space Systems OMS
    - Ready for flight program
  - Busek Multi-payload Utility Lite Electric (MULE)
    - Continuing development with ULA
- AFRL EAGLE (2017 launch to GEO)
  - Orbital ATK satellite bus and propulsion module
  - Moog Broad Reach avionics, software, GPS receiver
- Spaceflight SHERPA
  - Multiple implementations
- OMEGA (Orbiting Medium Explorer for Gravity Astrophysics)
  - Moog/Surrey US team reviewed by JPL TeamX in 2012

Current Vendors:

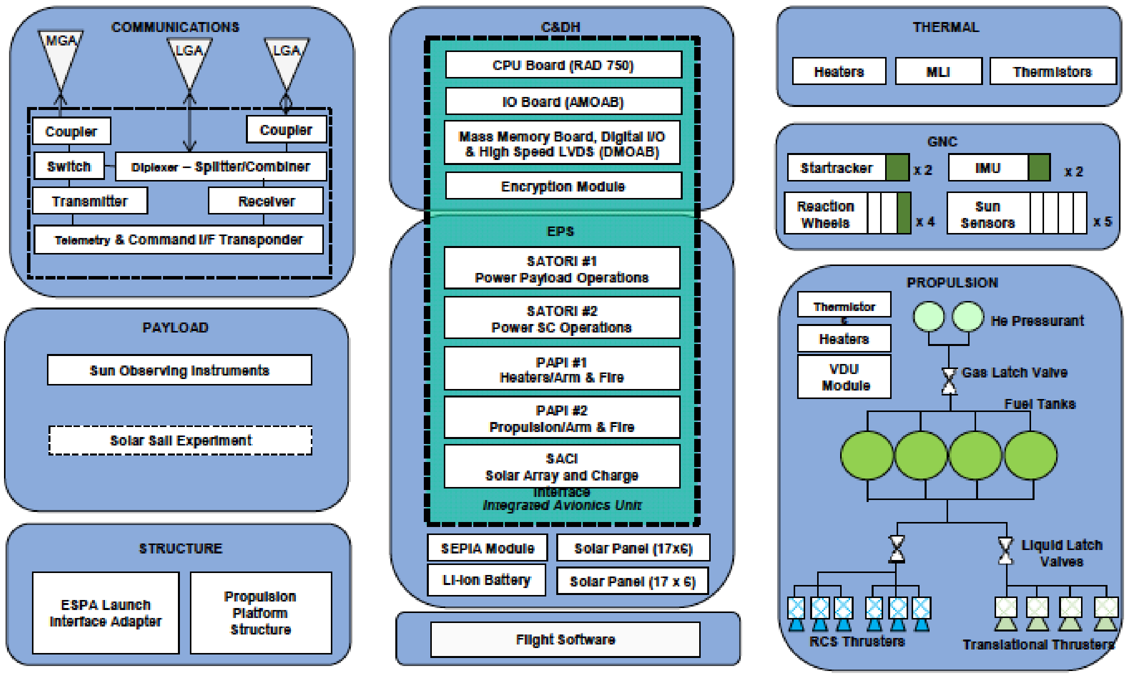
Moog CSA +

- Moog (BRE, ISP, etc.)
- Millennium
- Spaceflight Services
- ULA
- Boeing
- Northrup Grumman
- Orbital ATK
- Busek

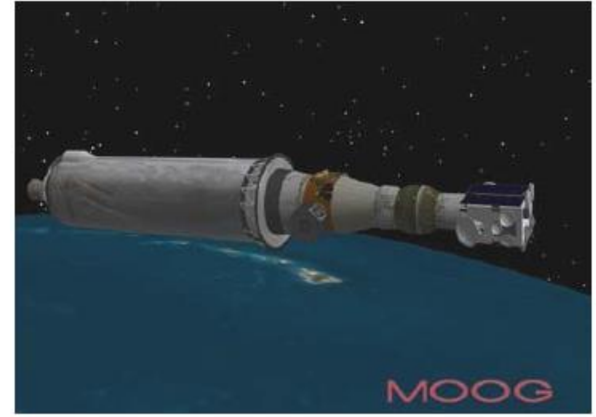
J. Maly, “Secondary Payload Adapters and Interfaces: Technical Committee Report
17th Annual Small Payload Rideshare Symposium, Johns Hopkins University/Applied Physics Lab, June 10, 2015

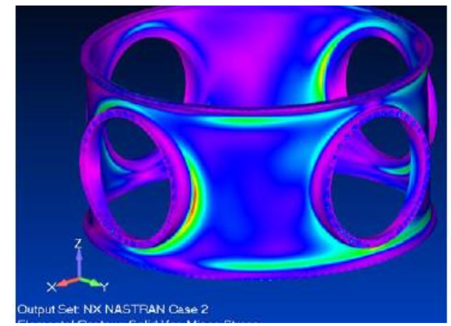
BACKUP

One-stop Shopping at Moog?



Selective redundancy for NASA Class C operational mission





Structure & mechanisms

Avionics

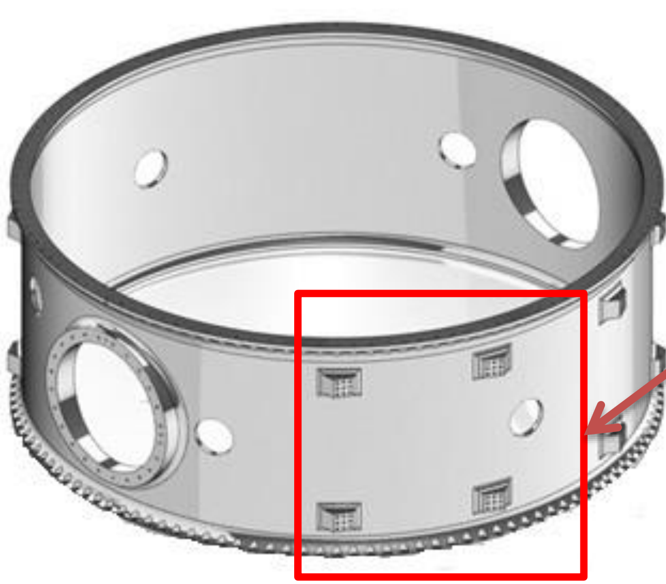
	MONARC-1	MONARC-5	MONARC-22-6	MONARC-22-12	MONARC-90LT	MONARC-90HT	MONARC-445
Engine							
Steady State Thrust	0.22 lbf (1N) @275 psia	1.0 lbf (4.5 N) @325 psia	5 lbf (22N) @275 psia	5 lbf (22N) @190 psia	20 lbf (90 N) @ 235 psia	26 lbf (116 N) @ 235 psia	100 lbf (445N) @ 275 psia

Propulsion

Power system

EAGLE:
ESPA Augmented Geostationary Laboratory Experiment

Interface developed for propulsive ESPA ring



Replace usual dispenser ports with 4-point-mount interface for attached hosted payloads

Both ports and 4-point-mounts can accommodate separable payloads:
180kg mass
20” CG offset from interface

STP Letter of Commitment for Goddard Proposals (TOMCAT & ThermaSat)

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SPACE AND MISSILE SYSTEMS CENTER (AFSPC)
LOS ANGELES AIR FORCE BASE, CALIFORNIA

30 November 2015

MEMORANDUM FOR Dr. Matt McGill
Goddard Space Flight Center
8800 Greenbelt Rd
Greenbelt, MD 20771

FROM: DIRECTOR, DOD SPACE TEST PROGRAM
3548 Aberdeen Ave. SE
Kirtland AFB, NM 87117

SUBJECT: Letter of Commitment for TOMCAT Mission

1. The DoD Space Test Program (STP) is pleased to support the Targeted Observational Monitoring of Cloud and Aerosol Transport (TOMCAT) mission being proposed by NASA Goddard. Upon proposal selection, the DoD STP will coordinate launch services in compliance with Air Force Instruction 10-1202 for NASA Goddard's TOMCAT mission. Per DoD policy, the STP is responsible for all non-DoD payloads obtaining launch opportunities on DoD launch vehicles or missions. STP will work with NASA Goddard to find a launch.

2. NASA Goddard will perform overall mission management for the TOMCAT mission and will provide the funding necessary for launch services. STP's partnership will facilitate cost savings for the mission's access to space. STP will coordinate launch opportunities and once approved, will manage the TOMCAT launch services.

3. The STP Rideshare process is captured in the Rideshare User's Guide (RUG) document. The RUG specifies acceptable analyses and test methodologies required to assure each Rideshare spacecraft is adequately qualified for Evolved Expendable Launch Vehicle (EELV) environments and operations with other spacecraft assigned to the launch. It also formally defines Rideshare Standard Service (RSS) and outlines the specific services provided by the Launch Vehicle Contractor (LVC) under contracts administered by the Space and Missile Systems Center (SMC) Launch Systems Enterprise Directorate (SMC/LE). Any services requested beyond those specified in the RUG are by definition "non-standard" and may require additional funding beyond SMC/LE's RSS funding. All costs resulting from non-standard rideshare related activities will be funded by the Rideshare customer or sponsor.

4. Based on past STP supported ESPA class missions, the rough order of magnitude (ROM) cost estimate for integrating the TOMCAT spacecraft on an ESPA ring (including launch site accommodation) is between \$1M and \$13M. This estimate is based on recent ESPA class missions and is driven by the impact of mission unique requirements (i.e. non-standard services). After TOMCAT is selected, STP will support a detailed accommodation study to access the interface requirements and develop a detailed cost estimate.

5. Please do not hesitate to contact my action officer, Mr. Lonny Webb at (505)846-8895 or e-mail lonny.webb.1@us.af.mil, if you have any questions.

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D. JASON COTHERN, Col, USAF
Director, DoD Space Test Program
Advanced Systems & Development Directorate
Space and Missiles System Center

DoD Space Test Program is formalizing Rideshare capabilities for non-DoD payloads:

- \$1M for CubeSat-type inert payload
- ≤\$13M for payload with complex interfaces and accommodation requirements
- Predictable secondary ride options